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Pitting corrosion of the stainless steel ventilation duct in a roofed swimming pool

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Abstract

On the surface of an uptake ventilation duct made of austenitic stainless steel, installed in a roofed swimming pool with chlorinated water, corrosion pits appeared after two years service. Chemical analysis of the duct sheet has shown, that it was made of X10CrNi18-8 austenitic steel. Microanalysis results of the corrosion deposits on the sheet surface revealed a high concentration of chlorine, which was also found in deposits located inside the corrosion pits. Discussion of the examination results and the survey of literature has led to the conclusion, that the corrosion resistance of the applied classical austenitic steel is not adequate for the ventilation installation in roofed swimming pools with chlorinated water, which belong to the highest group of corrosion hazards. The X10CrNi18-8 steel should be replaced in the new duct installation by a higher alloyed and Mo containing austenitic steel with a lower carbon content.

Keywords: Ventilation duct; Pitting corrosion; Austenitic stainless steel; Chlorinated water

1. Case presentation and introduction

In the swimming pool of a secondary school an uptake ventilation duct made of austenitic steel has been installed. After 2 years service, corrosion pits have been observed on the external surface of the ventilation duct elements (Fig. 1), but only few corroded areas were visible on the internal surface.

The water in the swimming pool is chlorinated by a special unit with a possibility of precise dosing of chlorine and monitoring of its content. According to the documentation, the chlorine concentration should be maintained at the limits of 0.3–0.5 mg/l, and the pH value should be kept in the range of 6.8–8.0. As shown on the display of the unit (Fig. 2) both values are maintained.

In order to find the reason of corrosion, an element of the ventilation duct has been delivered to the Institute of Welding (Fig. 3) for examination. Results of these examinations, performed in cooperation with the Institute for Ferrous Metallurgy are presented in this paper.

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Fig. 1. Ventilation duct with corroded surface.

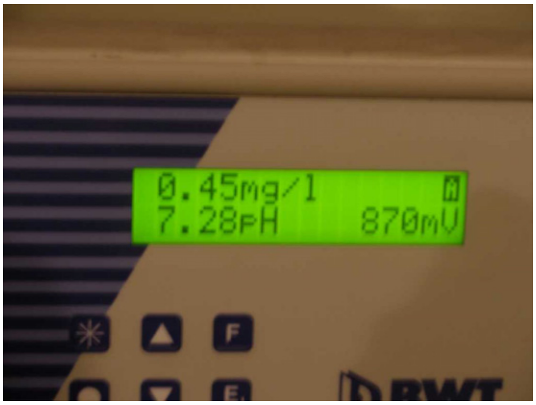


Fig. 2. Display of the chlorine concentration and pH value in the swimming pool water.

Fig. 3. View of the corroded ventilation duct element delivered for examination.

2. Course of examination and results

Visual examination of the ventilation duct element shown in Fig. 3, made of austenitic steel sheet 0.6 mm in thickness, has revealed, that the corrosion pits are present mainly on its external surface. On the internal sur-

face some corrosion centres are visible in the area of the assembly flange, which was resistance spot welded to the ventilation duct body (Fig. 4).

From the delivered ventilation duct element test pieces have been taken for chemical analysis and metallographic examination. The chemical composition of the steel, determined by spectroscopic analysis is given in Table 1.

The appearance of the corroded surface of the ventilation duct is shown in Fig. 5. Some corrosion pits have penetrated the sheet to a considerable depth (Fig. 6).

The chemical composition of the observed two types of deposits has been analyzed by electron microanalysis and the results are given in Fig. 7.

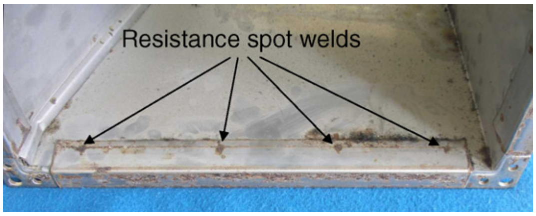


Fig. 4. Inside view of the ventilation duct element with corrosion centres close to the spot welded assembly flange.

Table 1
Chemical composition of the steel used for the ventilation duct in wt%

Item	C	Mn	Si	P	S	Cr	Ni	Mo	Cu
Steel from duct	0.048	1.30	0.73	0.027	0.012	17.55	7.17	0.13	0.19
X10CrNi18-8 steel acc. to PN-EN 10088-2 [1]	0.05–0.15	⩽2.00	⩽2.00	Max. 0.045	⩽0.015	16.0–19,0	6.0–9.0	⩽0.80	–

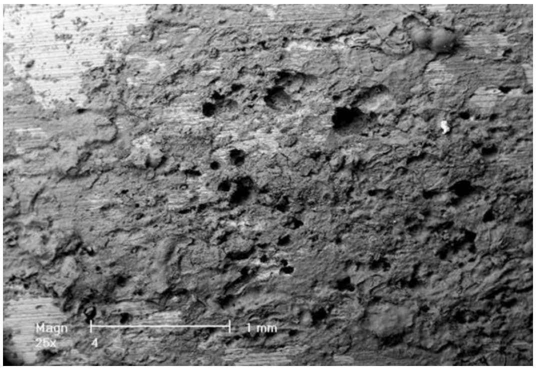


Fig. 5. The ventilation duct sheet with corrosion pits and deposits (SEM).

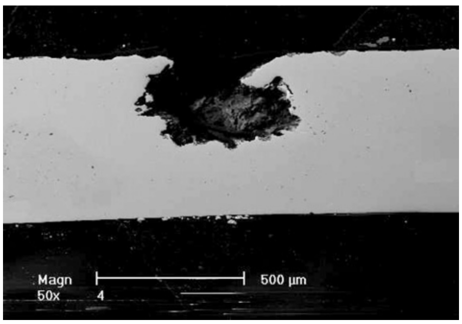
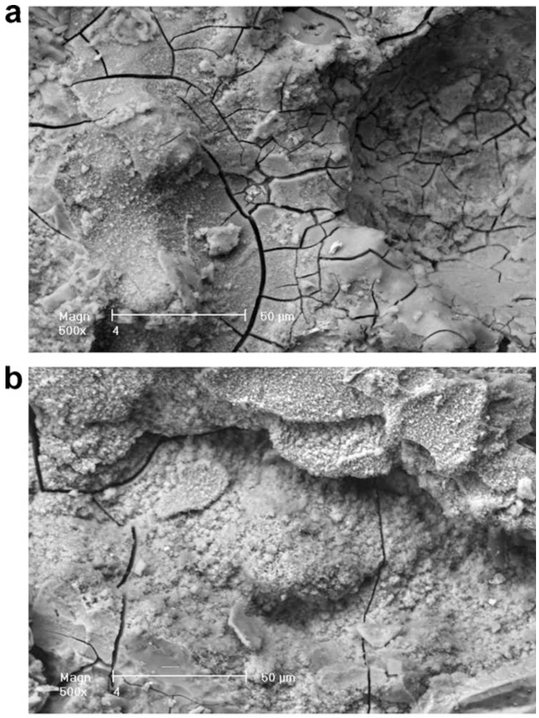


Fig. 6. Corrosion pit on the cross section of the ventilation duct sheet (SEM).



Element	A		B	
	% mass	% at.	% mas	% at.
O	7.41	19.06	9.68	25.10
Si	0.85	1.25	0.42	0.62
Cl	25.85	30.01	16.18	18.93
Cr	30.63	24.25	14.77	11.78
Mn	0.30	0.23	0.28	0.21
Fe	19.17	14.13	53.08	39.41
Ni	15.78	11.07	5.59	3.95

Fig. 7. Microanalysis results of chemical composition of two types deposits.

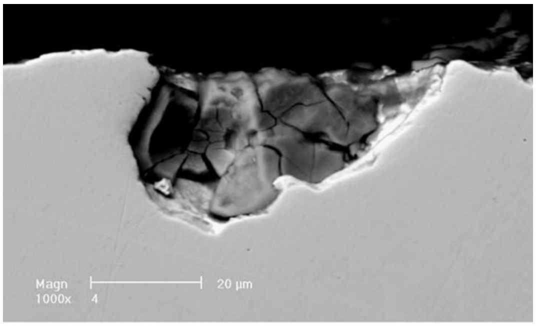
Some pits are filled with corrosion deposits, which chemical composition differs from those on the surface (Fig. 8).

3. Discussion of results

The chemical composition of the sheet from the ventilation duct complies with that of the X10CrNi18-8 steel acc. to PN-EN 10088-2 [1]. The small difference in carbon content is in agreement with the deviation for the product analysis, which is ±0.01%.

The X10CrNi18-8 steel used for the ventilation duct is a classical stainless steel, but for the service environment of the roofed swimming pool its corrosion resistance is not adequate. For the damp environment reach in chlorine, steels are needed with a lower carbon and higher nickel content and additionally alloyed with molybdenum. According to the German guidelines for the design and fabrication of stainless steel structures [2], the ventilation installations in roofed swimming pools with chlorinated water belong to the highest group of corrosion hazard. That guidelines recommend the following austenitic steels: X1NiCrMoCuN 25-20-7 (1.4529), X1CrNiMoCuN 20-18-7 or X1NiCrMoCu 25-20-5 (1.4539) acc. to PN-EN 10088-1:1998 [1].

In the analyzed case of the applied X10CrNi18-8 steel the observed pitting corrosion was the result of the underneath described phenomena which took place in the environment of the swimming pool.



Element	% mass	% at.
O	6.60	18.75
Si	0.85	1.38
Cl	5.37	6.89
Cr	39.91	34.90
Fe	37.10	30.21
Ni	10.17	7.88

Fig. 8. Microanalysis chemical composition results of deposit inside the corrosion pit.

In the majority of corrosion environments the stability of the passive protective layer is the result of its steady growth or renovation at places of local damage. The composition of the layer depends on the corrosion environment [3]. The presence of chlorides in a humid environment causes a decrease of corrosion resistance of austenitic steels. Chlorine ions depositing on the passive layer, as a result of a chemical reaction, locally dissolve the passive layer (depolarization), which leads to the formation of a pit. The deepening of the pit is the result of the formation of a thin layer of hydrochloric acid and hydroxide of the metal due to the reaction of chlorine ions with metal ions and water [4]. Acidification of the environment occurs inside the pit. In the case of the 18% Cr–8% Ni type stainless steel the pitting corrosion takes already place at 100 ppm of chlorine ions at the pH value in the range from 4 to 8 [4].

The sedimentation on the stainless steel sheet surface of water drops containing chlorides causes intensification of the corrosion processes by the interaction of chlorides – local depolarization process, pit formation and creation of cells with a non-uniform aeration [5].

During the drying process the corrosion products settle on the surface over the pits. Rewetting of the corrosion products by the water containing chlorides leads to deepening of the pits beneath the formed deposits. That type of under-deposit corrosion is a form of a concentration cell.

The high concentration of chlorine in the deposits on the stainless steel sheet surface (Fig. 7) and its lower content in the deposit inside the corrosion pit (Fig. 8) are the evidence of the described above corrosion mechanisms which took place on the ventilation duct exposed to the environment of the roofed swimming pool with chlorinated water.

As mentioned before, on the internal surface of the ventilation duct (Fig. 4) some corrosion centres are located at the assembly flange spot welded to the stainless steel sheet. It is crevice corrosion formed as a result of the gap between the flange and ventilation duct sheet. That kind of design should be avoided at high corrosion hazards.

On the internal surface of the ventilation duct sheet only a few corrosion spots can be observed (Figs. 3 and 4). The reason is a high rate of air flow through the duct, which prevents the condensing of chlorinated water on the sheet surfaces.

4. Conclusions

1. The reason of pitting corrosion of the uptake ventilation duct of the swimming pool, made of X10CrNi18-8 austenitic stainless steel, is the influence of chlorine ions in the wet environment.

2. The corrosion resistance of the X10CrNi18-8 steel is insufficient in that highly corrosive environment and should be replaced in the new installation by a higher alloyed Mo containing austenitic steel with a lower carbon content.
3. The assembly elements need also a new design, to avoid the possibility of crevice corrosion.

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